CLINICAL RESEARCH STUDIES

From the Eastern Vascular Society

Impact of hospital teaching status on survival from ruptured abdominal aortic aneurysm repair

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Objectives: **Controversy exists over the optimal hospital type to which high-risk surgical patients should be referred for operative management. While high volume centers have been traditionally advocated, recent evidence suggests teaching hospitals may have better outcomes for high-risk patients. We investigated whether mortality outcomes of patients undergoing surgery for ruptured abdominal aortic aneurysm (rAAA) were different between teaching hospitals and non-teaching hospitals, independent of hospital operative volume.**

Methods: **A retrospective review of the Nationwide Inpatient Sample dataset (1998-2004) was performed to identify open and endovascular (EVAR) repair for rAAA. Hospitals were stratified by teaching status, including teaching hospitals (TH) with any type of residency training program, those with general surgery training programs (GSTH) and those with vascular surgery training programs (VSTH). The association of hospital teaching status with in-hospital mortality for open AAA repair and EVAR was assessed via multi-level multivariable logistic regression, controlling for patient demographics, comorbidities, and hospital operative volume.**

Results: **Of 6636 open AAA repairs for rAAA, the overall perioperative mortality was 42%. Mortality was significantly lower at TH than non-TH (39.3% vs 44.5%; $P < .05$). Mortality was also lower at GSTH (38.7%) and VSTH (34.3%). After adjusting for hospital operative volume, patient demographics, and comorbidities, we found a 25% decrease in likelihood of in-hospital death at VSTH vs non-VSTH (odds ratio 0.75; 95% confidence interval 0.60-0.94; $P < .05$).**

Conclusion: **In-hospital mortality is significantly reduced for patients undergoing open AAA repair for rAAA at teaching hospitals and hospitals with vascular surgery training programs, independent of volume. These results suggest that in addition to factors associated with teaching hospitals in general, the type of specialty training within teaching institutions is a critical factor which may influence outcomes, specifically for patients with rAAA. (J Vasc Surg 2009;50:243-50.)**

Ruptured abdominal aortic aneurysms (rAAA) constitute a uniquely surgical emergency. The overall mortality following rAAA approximates 90%.[1] However, of those who survive transport to the hospital and subsequently undergo surgical intervention, approximately 50% survive.[2]

Recent focus on improving surgical quality and perioperative outcomes has been in part to define "centers of excellence" for high-risk procedures. This model suggests that patients should be directed to hospitals which have the best outcomes for given procedures. Perioperative outcomes have been shown to be improved for subspecialty trained vascular surgeons,[3,4] and increased hospital and surgeon volume have also been shown to play an important role in decreasing mortality.[4-6] Consequently, models used to define centers of excellence have primarily relied upon hospital and provider volume as measures of quality.

Debate persists over the importance for teaching hospitals, as well as the quality of care delivered by them. Patients frequently express hesitation over treatment by physicians-in-training, as well as the growing use of physician extenders and care providers undergoing training, which they will encounter during a hospital admission. Nevertheless, some recent studies have demonstrated improved care at teaching hospitals.[7-10]

It is unclear whether teaching hospital status, including the presence of specific residency and fellowship training programs, is associated with improved outcomes for complex and emergent vascular diseases. Furthermore, there is ongoing debate regarding whether favorable outcomes are due to increased patient volume or rather specific processes of care which occur at centers with multidisciplinary care and subspecialty training.[7,11] Therefore, we examined whether outcomes following open abdominal aortic aneurysm (AAA) repair and endovascular abdominal aortic aneurysms repair (EVAR) for rAAA are improved at teaching hospitals, or if improvement is due to volume alone.

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Competition of interest: none.

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MATERIALS AND METHODS

Data source. Patient data were collected from the Nationwide Inpatient Sample (NIS) file between 1998 and 2004. The NIS database is comprised of discharge records approximating a 20% sample of hospitals in the United States, and is maintained by the Agency for Healthcare Research and Quality (AHRQ) as part of the Healthcare Cost and Utilization Project.[12] It registers approximately 7 million patient discharge records per year, originating from approximately 1000 different hospitals per year nationwide. Data available within the NIS include patient and hospital demographics, payer information, treating and concomitant diagnoses, in-patient procedures, in-patient mortality, length of stay (LOS), and discharge destination. Data regarding the identification of hospitals with Accreditation Council for Graduate Medical Education (ACGME)-approved general surgery and vascular surgery residency training programs was obtained from the ACGME.[13] This retrospective study was approved by the Johns Hopkins University School of Medicine Institutional Review Board, who exempted the need for patient consent.

Patient selection. Inclusion criteria for this study were patients from the NIS database admitted with a diagnosis of rAAA as identified by the International Classification of Diseases, Ninth Revision (ICD-9) diagnosis codes 441.3 (abdominal aneurysm, ruptured).[14] This ICD-9 diagnosis code was then matched against patients who underwent open AAA repair as identified by ICD-9 Clinical Modification (ICD-9-CM) procedure code 38.44, and EVAR as identified by ICD-9-CM procedure code 39.71.[15]

Outcome variables. Discharge or in-hospital death was treated as the primary outcome from the operation and hospitalization. As the NIS is a record of discharge summaries, the time between operation and discharge or in-hospital death is variable. Patient-level independent variables examined included patient age, gender, race, comorbidities as measured by Charlson Index[16] and LOS. Hospital-level independent variables examined included teaching hospital (TH) status and annual hospital operative volume of open AAA repair and EVAR for rAAA.

Patient comorbidities were standardized using the Charlson Index[16] per the methods of Romano et al.[17] A standardized calculation of patient health and the Charlson Index is determined by weighted scoring of comorbidities including cardiac, vascular, pulmonary, neurological, endocrine, renal, hepatic, gastrointestinal, immune diseases, and any documented history of cancer. LOS was calculated excluding all in-hospital deaths.

The NIS dataset defines TH status as hospitals which have residency training approval by the ACGME, belong to the Council of Teaching Hospitals, or have a ratio of no more than 4:1 beds to full-time equivalent interns and residents.[12] Hospitals not identified as TH were termed non-TH. Using the hospital-identifying data available from the NIS dataset, the primary affiliate hospitals associated with ACGME-approved general surgery and vascular surgery residency training programs were identified. These hospitals were termed general surgery training hospitals (GSTH) and vascular surgery training hospitals (VSTH), respectively, during analysis. Hospitals lacking these programs were termed non-general surgery training hospitals (non-GSTH) and non-vascular surgery training hospitals (non-VSTH), respectively.

Hospital-identifying data was not available in the NIS database for the following states: Arkansas, Georgia, Hawaii, Indiana, Kansas, Michigan, Nebraska, Ohio, South Carolina, South Dakota, Tennessee, and Texas. Consequently, all (1318) patients from these states, regardless of hospital status, were excluded from the analysis of GSTH and VSTH. These patients were, however, included in the comparison of TH vs non-TH, as TH status was known for them.

Individual annual hospital operative volume was determined by calculating the number of all open AAA repairs or EVAR for rAAA performed per hospital per year, and was examined as a continuous variable. Subgroup analysis and cross-comparisons were performed between TH, GSTH, and VSTH, as well as non-TH, non-GSTH, and non-VSTH.

Statistical analysis. Statistical analysis was performed using the statistical software package Stata version 10.2 (College Station, Tex). Bivariate analysis of categorical data was performed using the χ^2 test. Analysis of continuous data was performed using *t* test. Multi-level random effects models were used to adjust for confounding and test for interactions between variables at the hospital and patient level. The model used (generalized estimating equation) estimated the population averaged odds of death for the average patient who underwent surgery for rAAA. This model accounts for the clustering of individual patients within hospitals. Variables included were clinically and statistically significant by bivariate analysis. A *P* value of $\leq .05$ was considered to be statistically significant for all tests.

RESULTS

Study population. Between January 1, 1998, and December 31, 2004, 11,470 patients in the NIS were diagnosed with rAAA on discharge summary. Of these patients, 4441 (38.7%) did not undergo surgical repair. Additional exclusion criteria included age less than 18 years, unknown vital status, and unknown hospital teaching status on discharge summary. Two patient records were dropped because they were recorded as having undergone both open AAA repair and EVAR. This limited our study cohort to 7005 patients from 2374 different hospitals. Results are reported on these patients. Of these, 6636 patients underwent open AAA repair for rAAA, while 369 underwent EVAR for rAAA.

Overall, there were 5500 males (78.5%) in the study group, and the median age of the study group was 74 years. The racial breakdown of this group included 4727 (67.5%) white, 257 (3.7%) black, 324 (4.6%) other, and 1697 (24.2%) patients of unknown race. The median Charlson Index score was 2 (interquartile range [IQR]: 1-3).

Table I. Characteristics of patients undergoing open AAA repair for rAAA performed at teaching and non-teaching hospitals

	Teaching hospitals	*Non-teaching hospitals*	P *value*
Patient characteristics			
Patients (%)	3206 (48.3%)	3430 (51.7%)	
Mean age in years (median)	73.0 (73)	73.4 (73)	.1
Male gender (%)	2467 (77.0%)	2746 (80.1%)	.002
Race: (%)			<.001
White	2021 (63.0%)	2468 (72.0%)	
Black	151 (4.7%)	87 (2.5%)	
Other	141 (4.4%)	164 (4.8%)	
Unknown	893 (27.9%)	711 (20.7%)	
Mean Charlson Index Score (median)	2.1 (2)	2.1 (2)	.9
Mean length of stay in days excluding patients who died during admission (median)	19.2 (13)	16.1 (12)	.001
Hospital characteristics			
Hospitals (%)	859 (37.0%)	1462 (63.0%)	
In-hospital deaths (%)	1261 (39.3%)	1525 (44.5%)	<.001
Median annual hospital volume of open abdominal aneurysm repairs (IQR)	5 (3-9)	3 (2-5)	<.001
Annual number of open AAA repairs of rAAA (%)			<.001
1998	542 (16.9%)	631 (18.4%)	
1999	589 (18.4%)	572 (16.7%)	
2000	440 (13.7%)	597 (17.4%)	
2001	480 (15.0%)	520 (15.2%)	
2002	418 (13.0%)	460 (13.4%)	
2003	371 (11.6%)	357 (10.4%)	
2004	366 (11.4%)	293 (8.5%)	

AAA, Abdominal aortic aneurysm; *rAAA,* ruptured abdominal aortic aneurysm; *IQR,* interquartile range.

Open AAA repair. Patient demographics were similar for the 6636 patients who underwent open AAA repair for rAAA at 2321 hospitals. The median annual hospital volume for open AAA repair was 4 (IQR: 2-7) with a range from 1 to 27. There were 2786 in-hospital deaths, constituting an overall mortality rate of 42%. The number of open AAA repairs decreased each year, with a total of 1173 in 1998, 1161 in 1999, 1037 in 2000, 1000 in 2001, 878 in 2002, 728 in 2003, and 659 in 2004. Excluding those patients who died, LOS ranged from 0 to 282 days, with a median of 12 days, and mean of 17.6 days.

Teaching hospital status. Select demographics of the study population comparing open AAA repair for rAAA at TH and non-TH are presented in Table I. There were 3206 (48.3%) open AAA repairs for rAAA performed at 859 TH, and 3430 (51.7%) open AAA repairs for rAAA at 1462 non-TH. The median annual hospital surgical volume at TH was significantly greater than that at non-TH (5 vs 3, $P < .001$). The in-hospital mortality rate for open AAA repair for rAAA at TH was 39.3%, significantly less than 44.5% at non-TH ($P < .001$). This is represented in Fig 1.

Patients were of comparable age and Charlson Index of comorbidities, however, more females were treated at TH than at non-TH (23% vs 19.9%, $P = .002$). The distribution of patient race also differed between TH and non-TH populations ($P < .001$). Median LOS, excluding in-hospital deaths, was significantly shorter at non-TH than TH (12 vs 13 days, $P = .001$). The distribution of procedures by year for TH differed significantly from non-TH ($P < .001$), with a trend in both towards fewer open AAA repairs each subsequent year in the study sample.

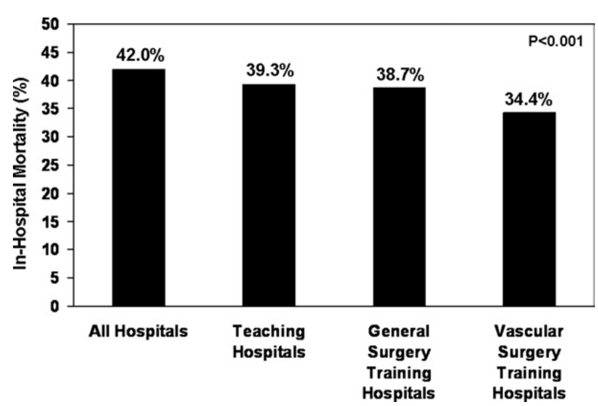

Fig 1. In-hospital mortality rates for patients undergoing open abdominal aortic aneurysm repair for ruptured abdominal aortic aneurysm by hospital teaching status. Univariate comparison of mortality rates reveals $P < .001$.

General surgery training hospital status. The characteristics of procedures performed at GSTH and non-GSTH are presented in Table II. Only 211 (9.1%) hospitals were characterized as GSTH, at which 1042 (19.6%) of the procedures were performed. The in-hospital mortality rate for open AAA repair for rAAA at GSTH was 38.7% as compared to 43.7% at non-GSTH ($P = .003$), presented in Fig 1. The median annual hospital operative volume was

Table II. Characteristics of patients undergoing open AAA repair for rAAA by surgical specialty teaching hospital status

	General surgery training hospitals	*Non-general surgery training hospitals*	P *value*	*Vascular surgery training hospitals*	*Non-vascular surgery training hospitals*	P *value*
Patient characteristics						
Patients (%)	1042 (19.6%)	4276 (80.4%)		497 (9.4%)	4821 (90.6%)	
Mean age in years (median)	73.3 (74)	73.6 (74)	.4	72.8 (73)	73.6 (74)	.06
Male gender (%)	774 (74.3%)	3369 (78.8%)	.002	352 (70.8%)	3791 (78.6%)	<.001
Race: (%)			<.001			<.001
White	729 (70.0%)	2959 (69.2%)		335 (67.4%)	3353 (69.6%)	
Black	61 (5.8%)	109 (2.6%)		32 (6.4%)	138 (2.9%)	
Other	54 (5.2%)	179 (4.2%)		17 (3.5%)	216 (4.5%)	
Unknown	198 (19.0%)	1029 (24.1%)		113 (22.7%)	1114 (23.1%)	
Mean Charlson Index Score (median)	2.0 (2)	2.1 (2)	.05	2.1 (2)	2.1 (2)	.2
Mean length of stay in days excluding patients who died during admission (median)	21.2 (15)	16.9 (12)	<.001	22.6 (16)	17.2 (12)	<.001
Hospital characteristics						
Hospitals (%)	211 (9.1%)	2,110 (90.9%)		91 (3.9%)	2,230 (96.1%)	
In-hospital deaths (%)	403 (38.7%)	1,870 (43.7%)	.003	171 (34.4%)	2,102 (43.6%)	<.001
Median annual hospital volume of open abdominal aneurysm repairs (IQR)	5 (3-9)	3 (2-5)	<.001	8 (5-10)	4 (2-6)	<.001
Annual number of open AAA repairs of rAAA (%)			<.001			<.001
1998	130 (12.5%)	839 (19.6%)		45 (9.0%)	924 (19.2%)	
1999	198 (19.0%)	798 (18.7%)		91 (18.3%)	905 (18.8%)	
2000	137 (13.2%)	716 (16.7%)		53 (10.7%)	800 (16.6%)	
2001	170 (16.3%)	614 (14.4%)		91 (18.3%)	693 (14.4%)	
2002	131 (12.6%)	571 (13.4%)		66 (13.3%)	636 (13.2%)	
2003	135 (13.0%)	385 (9.0%)		78 (15.7%)	442 (9.2%)	
2004	141 (13.5%)	353 (8.3%)		73 (14.7%)	421 (8.7%)	

AAA, Abdominal aortic aneurysm; *rAAA,* ruptured abdominal aortic aneurysm; *IQR,* interquartile range.

significantly higher at GSTH as compared to non-GSTH (5 vs 3, $P < .001$).

Patients were of comparable age and Charlson Index of comorbidities, however, more females were treated at GSTH than at non-GSTH (25.7% vs 21.2%, $P = .002$). Distribution of patient race also differed between GSTH and non-GSTH populations ($P < .001$). Median LOS was significantly shorter at non-GSTH than GSTH (12 vs 15 days, $P < .001$). The distribution of procedures by year for GSTH differed significantly from non-GSTH ($P < .001$), and there was a trend towards fewer open AAA repairs per year at non-GSTH during the time period of the study.

Vascular surgery training hospital status. A similar subgroup analysis was performed comparing outcomes at VSTH to non-VSTH. Characteristics of procedures performed at these hospitals are presented in Table II. Of the 2374 hospitals in the study sample, 91 (3.8%) were VSTH, at which 497 (9.4%) open AAA repairs were performed. In comparison, 4821 (90.6%) of open AAA repair for rAAA were performed at 2230 non-VSTH hospitals. The in-hospital mortality rate of open AAA repair for rAAA at VSTH was 34.3% as compared to 43.6% at non-GSTH ($P < .001$), as presented in Fig 1. The median annual hospital volume was significantly higher at VSTH as compared to non-VSTH (8 vs 4, $P < .001$).

Patients were of comparable age and Charlson Index of comorbidities, however, more females were treated at VSTH than at non-VSTH (29.2% vs 21.4%, $P < .001$). Distribution of patient race differed between VSTH and non-VSTH populations ($P < .001$). Median LOS was significantly shorter at non-VSTH than VSTH (12 vs 16 days, $P < .001$). The distribution of procedures by year for VSTH differed significantly from non-VSTH ($P < .001$), and again there was a trend towards fewer open AAA repairs per year at non-VSTH over the time period of the study.

Multivariate analysis. The association between open AAA repair for rAAA and likelihood of in-hospital death was evaluated using a multi-level random effects multivariate logistic regression analysis after stratifying by hospital teaching status. These results are shown in Table III. The basic model tested controlled for the confounding variables of patient age, gender, race, Charlson Index of comorbidities, and hospital teaching status. The likelihood of in-hospital death was independently reduced by 18% for patients undergoing open AAA repair for rAAA at TH compared to non-TH ($P < .001$). This difference in survival was further magnified at GSTH compared to non-GSTH (21% reduction in risk of death, $P = .003$), and at VSTH compared to non-VSTH (33% reduction in risk of death, $P < .001$).

Table III. Adjusted odds ratio of in-hospital death for patients undergoing open AAA repair for rAAA based on hospital teaching status*

Model tested	*Odds ratio*	*95% Confidence interval*	P *value*
Teaching hospitals			
Multi-level model controlling for each hospital	0.82	0.74-0.91	<.001
Multi-level model controlling for each hospital and operative volume	0.87	0.78-0.98	.02
General surgery training hospitals			
Multi-level model controlling for each hospital	0.79	0.68-0.92	.003
Multi-level model controlling for each hospital and operative volume	0.87	0.74-1.02	.1
Vascular surgery training hospitals			
Multi-level model controlling for each hospital	0.67	0.54-0.84	<.001
Multi-level model controlling for each hospital and operative volume	0.75	0.60-0.94	.01

AAA, Abdominal aortic aneurysm; *rAAA,* ruptured abdominal aortic aneurysm.
*Basic logistic regression model includes hospital teaching status, patient age, gender, race, and Charlson index of comorbidities.

To determine if hospital teaching status was a proxy for surgical volume, a multi-level random effects multivariate logistic regression analysis was performed among each of the different hospital types, accounting for annual hospital volume and comparing odds of in-hospital death after surgery at TH vs non-TH, GSTH vs non-GSTH, and VSTH vs non-VSTH. When annual hospital operative volume was included as a continuous variable the difference in odds of survival observed between TH and non-TH was diminished, but remained significant (odds ratio [OR] = 0.87, P = .02). The difference in odds of survival observed between GSTH and non-GSTH became non-significant (OR = 0.87, P = .1). However, the difference in odds of survival between VSTH and non-VSTH remained significant (OR = 0.75, P = .01). The ORs for in-hospital death for open AAA repair for rAAA controlling for patient age, gender, race, Charlson Index of comorbidities, hospital teaching status, and operative volume for the different types of teaching hospital are shown in Fig 2.

EVAR. Subsequent to the existence of an IDC-9 diagnosis code for EVAR (October 2000), 369 patients underwent EVAR at 247 hospitals in the dataset. The median age of patients undergoing EVAR for rAAA was 75 years (IQR 68-81), 22.2% (82) of patients were female, and median Charlson index was 2. Excluding those patients who died, mean LOS was 13.1 days (median 9 days). Overall in-hospital mortality was 33.3%. There was an increase in the number of EVARs performed each year between 2001 (74 EVAR) and 2004 (114 EVAR).

Comparison of EVAR for rAAA at TH vs non-TH reveals similar patient demographics and LOS (Table IV). Two hundred forty-two patients underwent EVAR at 144 TH, as compared to 127 patients at 103 non-TH. The resulting median annual hospital volumes were 2 at TH and 1 at non-TH, which were significantly different (P = .005). The in-hospital mortality rates were significantly different; 26% at TH and 47.2% at non-TH (P < .001).

Similar patient demographics and LOS also exist for patients who underwent EVAR for rAAA at GSTH vs non-GSTH, and VSTH vs non-VSTH (Table V). One hundred twenty-three patients underwent EVAR at 60 GSTH, as compared to 181 patients at 187 non-GSTH. The resulting median annual hospital volumes were 3 at GSTH and 1 at non-GSTH, which were significantly different (P < .001). The in-hospital mortality rates were significantly different; 25.2% at GSTH and 38.7% at non-GSTH (P = .01).

Ninety-one patients underwent EVAR at 36 VSTH, as compared to 213 patients at 211 non-VSTH. The resulting median annual hospital volumes were 4 at VSTH and 1 at

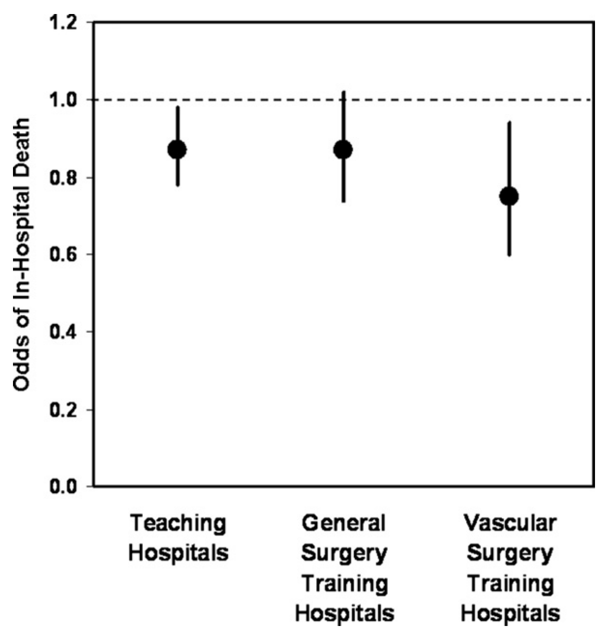

Fig 2. Adjusted odds ratio of in-hospital mortality for patients undergoing open abdominal aortic aneurysm (AAA) repair of ruptured abdominal aortic aneurysm (rAAA) by hospital teaching status. Point estimate with 95% confidence intervals for risk of in-hospital death for patients undergoing open AAA repair for rAAA at each type of teaching hospital as compared to those hospitals lacking that type of hospital teaching status. Multi-level random effects multivariable logistic regression includes hospital teaching status, patient age, gender, race, Charlson index of comorbidities, and annual hospital volume of open AAA repair for rAAA.

Table IV. Characteristics of patients undergoing EVAR for rAAA performed at teaching and non-teaching hospitals

	Teaching hospitals	*Non-teaching hospitals*	P *value*
Patient characteristics			
Patients (%)	242 (65.6%)	127 (34.4%)	
Mean age in years (median)	73.7 (74)	74.8 (76)	.2
Male gender (%)	189 (78.1%)	98 (77.2%)	.8
Mean Charlson Index Score (median)	2.2 (2)	2.4 (2)	.3
Mean length of stay in days excluding patients who died during admission (median)	12.0 (9)	15.9 (10)	.6
Hospital characteristics			
Hospitals (%)	144 (58.3%)	103 (41.7%)	
In-hospital deaths (%)	63 (26.0%)	60 (47.2%)	<.001
Median annual hospital volume of open abdominal aneurysm repairs (IQR)	2 (1-3)	1 (1-2)	.005
Annual number of EVAR of rAAA (%)			.07
2000 (beginning in October)	5 (2.1%)	4 (3.2%)	
2001	43 (17.8%)	31 (24.4%)	
2002	46 (19.0%)	32 (25.2%)	
2003	62 (25.6%)	32 (25.2%)	
2004	86 (35.5%)	28 (22.0%)	

EVAR, Endovascular aneurysm repair; *rAAA*, ruptured abdominal aortic aneurysm; *IQR*, interquartile range.

Table V. Characteristics of patients undergoing EVAR for rAAA by surgical specialty teaching hospital status

	General surgery training hospitals	*Non-general surgery training hospitals*	P *value*	*Vascular surgery training hospitals*	*Non-vascular surgery training hospitals*	P *value*
Patient characteristics						
Patients (%)	123 (40.5%)	181 (59.5%)		91 (29.9%)	213 (70.1%)	
Mean age in years (median)	74.1 (74)	74.3 (75)	.9	73.9 (74)	74.4 (75)	.7
Male gender (%)	99 (80.5%)	139 (76.8%)	.4	72 (79.1%)	166 (77.9%)	.8
Mean Charlson Index Score (median)	2 (2.2)	2.3 (2)	.3	2.3 (2)	2.3 (2)	.9
Mean length of stay in days excluding patients who died during admission (median)	12.0 (9.5)	14.3 (9)	.8	11.3 (10)	14.3 (9)	.5
Hospital characteristics						
Hospitals (%)	60 (24.3%)	187 (75.7%)		36 (14.6%)	211 (85.4%)	
In-hospital deaths (%)	31 (25.2%)	70 (38.7%)	.01	18 (19.8%)	83 (39.0%)	.001
Median annual hospital volume of open abdominal aneurysm repairs (IQR)	3 (1-5)	1 (1-2)	<.001	4 (2-5)	1 (1-2)	<.001
Annual number of EVAR of rAAA (%)			.008			.001
2000 (beginning in October)	4 (3.3%)	4 (2.2%)		2 (2.2%)	6 (2.8%)	
2001	21 (17.1%)	40 (22.1%)		12 (13.2%)	49 (23%)	
2002	18 (14.6%)	54 (29.8%)		11 (12.1%)	61 (28.6%)	
2003	37 (30.1%)	43 (23.8%)		34 (37.4%)	46 (21.6%)	
2004	43 (35.0%)	40 (22.1%)		32 (35.2%)	51 (23.9%)	

non-VSTH, which were significantly different ($P < .001$). The in-hospital mortality rates were significantly different; 19.8% at VSTH and 39% at non-VSTH ($P = .001$).

DISCUSSION

Controversy exists over the optimal hospital type to which high-risk surgical patients should be referred for operative management. While high volume centers have been traditionally advocated, recent evidence suggests THs may have better outcomes for high-risk patients. Our data support these findings showing that mortality rates for ruptured AAA repairs were significantly lower at hospitals defined by teaching status at several different levels even after controlling for volume. Indeed, when patients with rAAA were stratified by whether they received care in hospitals that contain a vascular surgery training program, we found a 25% lower mortality associated with teaching status using adjusted multi-level regression models. These findings suggest that a hospital's teaching status is an important factor to consider when triaging patients with rAAA and possibly other acute vascular surgery emergencies.

While the addition of annual hospital operative volume did attenuate the effect of TH status for all comparisons tested, it is important to note that in none of these cases did the OR of in-hospital mortality return to 1. This suggests the effect modification attributable to the different types of hospital teaching status is persistent independent of volume. However, given that the addition of operative volume to the different analyses did decrease the significance of the different TH status, this analysis underlines the continued importance of hospital operative volume for improved outcomes after open AAA repair for rAAA. Volume appears to be an important factor in improved outcome observed at TH and GSTH. Therefore, one conclusion from this analysis is that increased operative volume is correlated with decreased risk of in-hospital death after open AAA repair for rAAA. These findings are aligned with those reported by others.[3,5,6]

The use of EVAR in rAAA has been increasing in popularity over the past decade.[18] This was reflected in our data as with each subsequent year of data analysis beyond 2000, the number of EVARs performed in the dataset increased. Given that the numbers reported, and associated data available, are very low, we were unable to perform a robust, multi-level analysis on the effect of teaching hospital status on EVAR for rAAA. Simple multivariable logistic regression was performed (results not shown) with results qualitatively comparable to the multi-level analysis for open AAA repair. We focus, therefore, on the outcomes of open AAA repair for rAAA so as to measure the impact of TH status on patients undergoing surgery for rAAA.

It is interesting to note the trend in decreasing operative volume of open AAA repair over the 7 years of the study. Also interesting is progression to fewer open procedures performed at non-TH vs at TH (18.4% in 1998 to 8.5% in 2004 at non-TH vs 16.9% in 1998 to 11.4% in 2004 at TH). The progressive decrease in open AAA repair for rAAA is consistent with the recent trend towards endovascular management. However, upon examination of annual volumes of EVAR beginning at the end of 2000, the combined volumes of open AAA repair and EVAR for rAAA do not remain constant, but still decrease over time. This, therefore, suggests that there is a declining incidence in rAAA undergoing surgical management. We speculate this may be associated with population screening and an increase in comorbidity threshold for repair of AAA given the decreased perioperative mortality of EVAR as it has become more widely used, with the result that fewer AAA are presenting as ruptured.

LOS was calculated excluding all in-hospital deaths. However, it does not exclude patients who were transferred to other hospitals postoperatively. Unfortunately, this database combines transfer destinations of skilled nursing facilities with hospitals for acute care. Progressively longer LOS at TH, GSTH, and VSTH may reflect sicker patients being treated at these hospitals, or a decreased threshold for postoperative transfer of patients from non-TH to other hospitals. In-depth analysis of this trend is not the focus of this study, and further analysis of this observation is warranted.

The administrative NIS database was chosen over other available databases due to the extensive nature of its records and the ability to provide a large sample size with which to compare outcomes across the United States. Limitations include the retrospective database design and the associated constraints at the level of the data used for analysis; the inability to account for variations in surgical technique; the identification of TH status by criteria determined by the AHRQ in the NIS, and the difficulty in examining other postoperative outcomes, complications, and cause of death.

The findings of our study suggest that not simply TH status acts as a surrogate for improved perioperative outcomes for rAAA repair, but a process of care specific to hospitals with vascular surgery fellowships. Donabedian[19] proposed that the quality of healthcare is assessed on the basis of structure, process, and patient outcomes. Several processes of care associated with THs have been described and associated with improved patient outcomes.[20-24] These include dedicated surgical intensive care units managed by intensive care specialists and patient safety initiatives.[25] The use of multidisciplinary teams, specialty-specific patient units, and standardized clinical care pathways at high volume centers, have been shown to improve outcomes for high-risk patients following complex procedures.[26] Though these processes of care may be available in varying degrees at all hospitals, teaching status may serve as a surrogate for them in large databases including the NIS.

Sub-specialty surgical training may further contribute to the improved outcomes seen at THs. Silvestri[27] demonstrated significantly decreased mortality rates in patients undergoing lung resection by board-certified thoracic surgeons than by general surgeons. This same difference in outcome of lung resections has been described between cardiovascular and general thoracic surgeons, favoring the latter.[28]

We believe it is important to identify and understand the processes of care associated with improved outcomes after EVAR as well as open AAA repair. One can speculate critical factors at this juncture in the use of EVAR to include operator familiarity with the technique and multitude of endovascular products on the market. This is similar to the growth curve observed with the advent of laparoscopic techniques in general surgery.[29-31]

On consideration of the limitations of our study, in conjunction with the finding of others, it is likely that VSTH status is a surrogate marker for the structure and process of providing surgical management for rAAA which contribute to improved perioperative survival. While the processes of care previously described are certainly not specific to THs alone, ultimately all vascular surgery outcomes would be improved if they were widely available at teaching and non-teaching hospitals, large and small. These results suggest the type of specialty training within teaching institutions is a critical factor which may determine outcomes, specifically for patients with ruptured AAA.

AUTHOR CONTRIBUTIONS

Conception and design: RM, BB, BP, JF
Analysis and interpretation: RM, BB, BP, JF
Data collection: RM, BB
Writing the article: RM, BB, BP, JF
Critical revision of the article: RM, BB, BP, JF
Final approval of the article: RM, BB, BP, JF
Statistical analysis: RM, BB
Obtained funding: BP, JF
Overall responsibility: RM

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